Automatic Optical Image Stabilization system calibration, validation, and performance for the SkySat constellation

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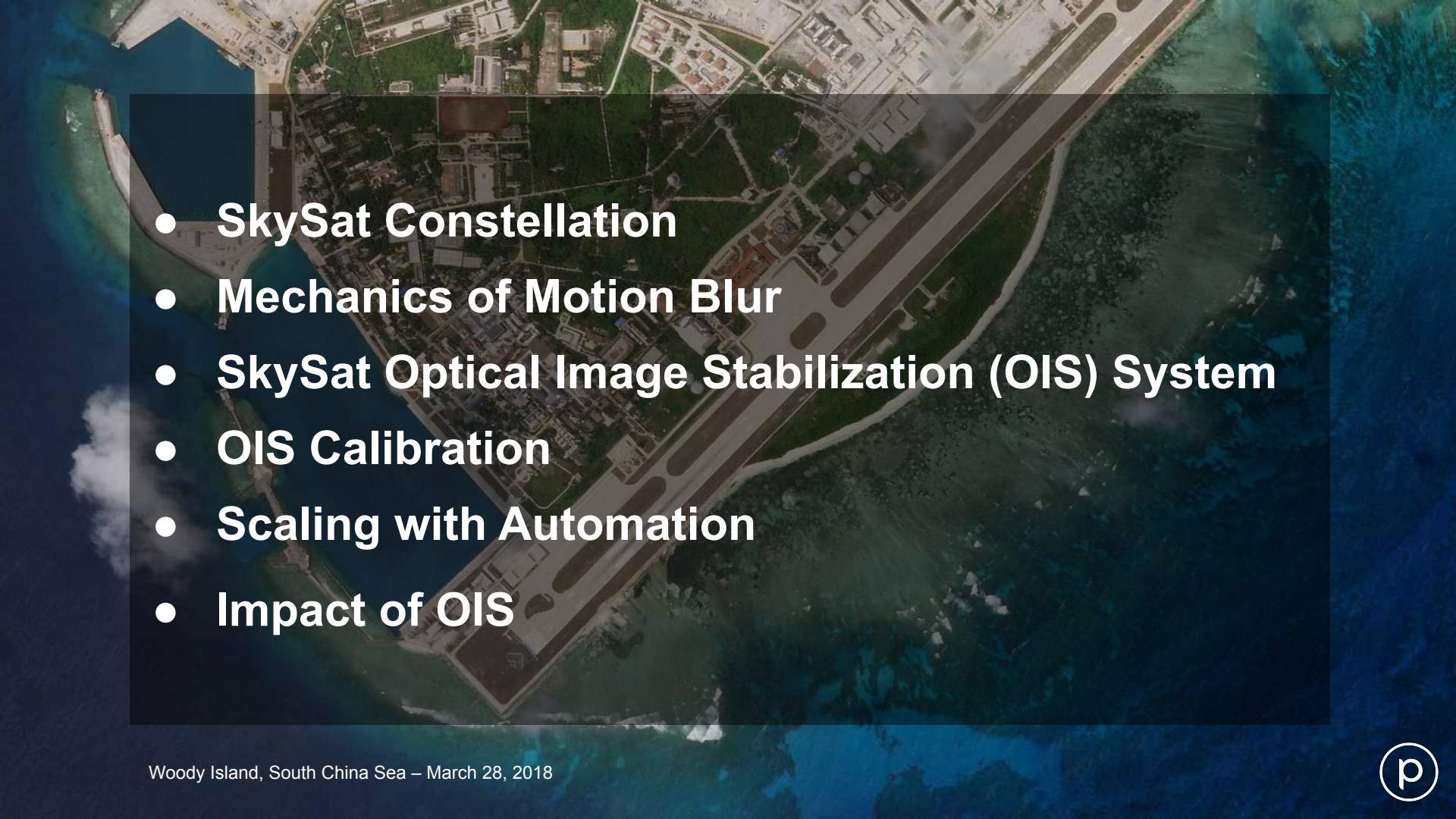


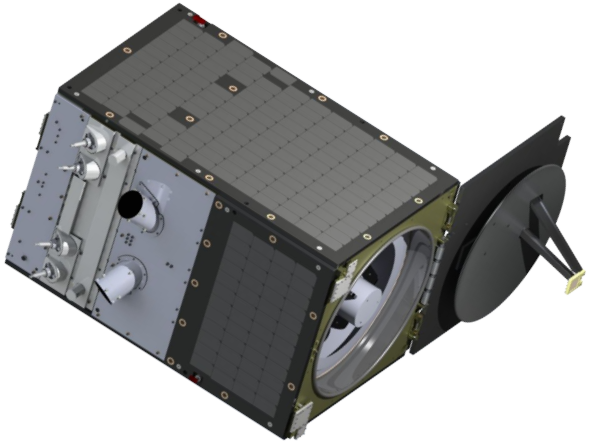
- SkySat Constellation
- Mechanics of Motion Blur
- SkySat Optical Image Stabilization (OIS) System
- OIS Calibration
- Scaling with Automation
- Impact of OIS

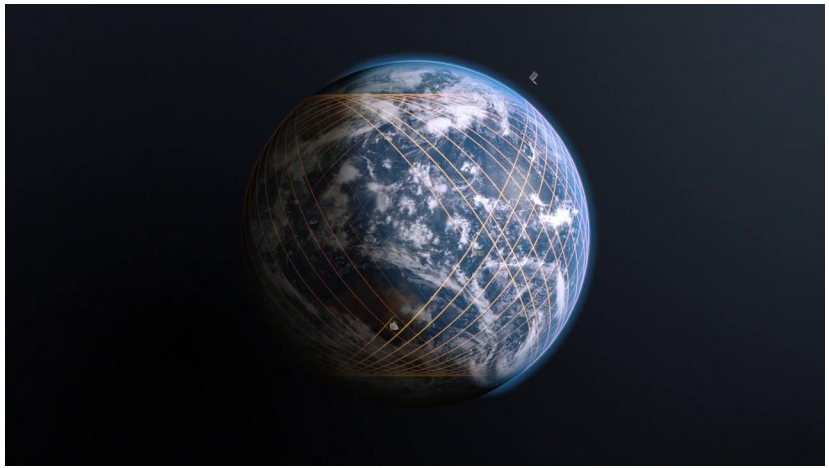
Woody Island, South China Sea – March 28, 2018

SkySat Constellation

High Resolution EO Small Sats

- Tasked imaging conops
- Step-stare collection scheme
- Multiple orbital planes

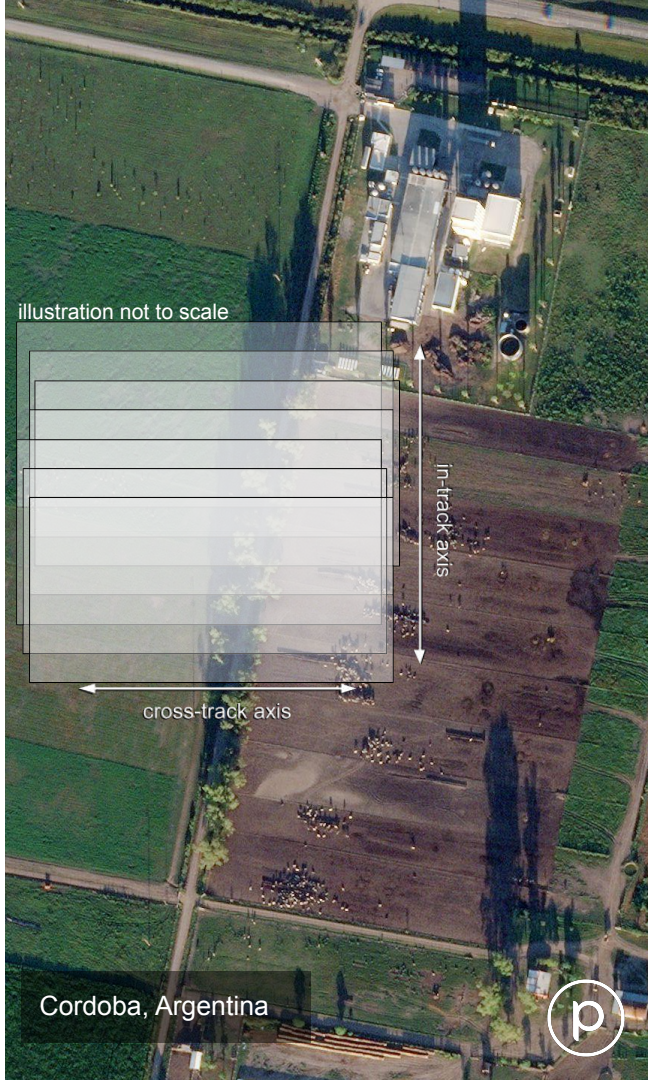




Mechanics of Motion Blur

Scanning over a region

- The camera integrates signal on the sensor over time to capture an image
- When the scene moves during integration, the image has motion blur
- Scanning across the ground faster incurs more motion blur, but means we can take more images per orbit



Mechanics of Motion Blur

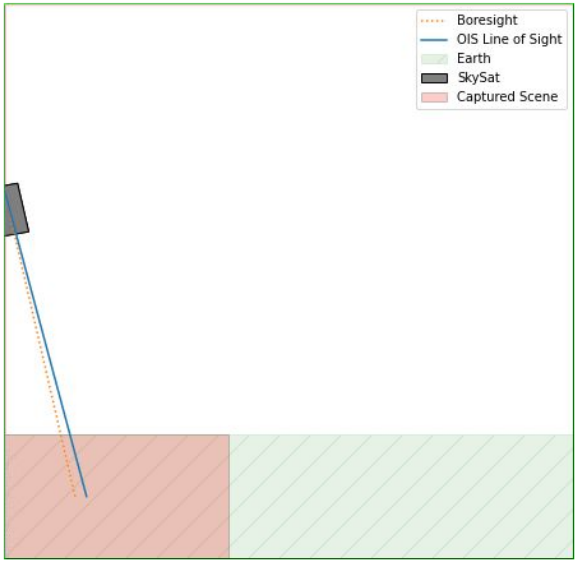
Direct comparison: same scan rate, OIS off/on

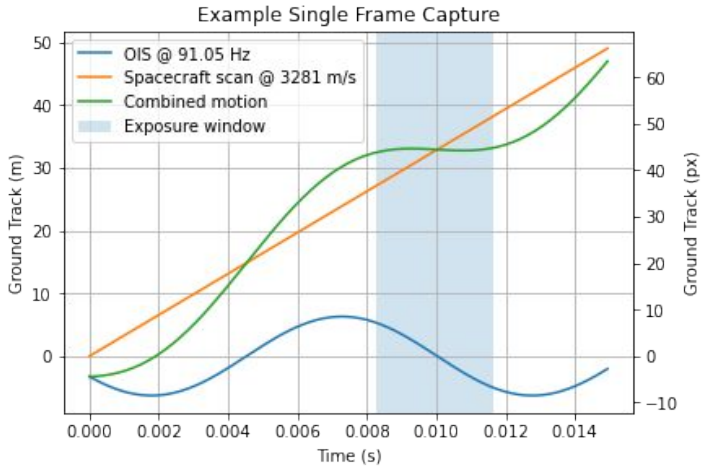
OIS

Mechanics of Motion Blur

Reducing scene motion with vibration

- Introducing sinusoidal oscillation results in periods of very low relative motion
- Capture images during periods of low relative motion for minimal blur
- Enables faster scanning with no degradation in image quality

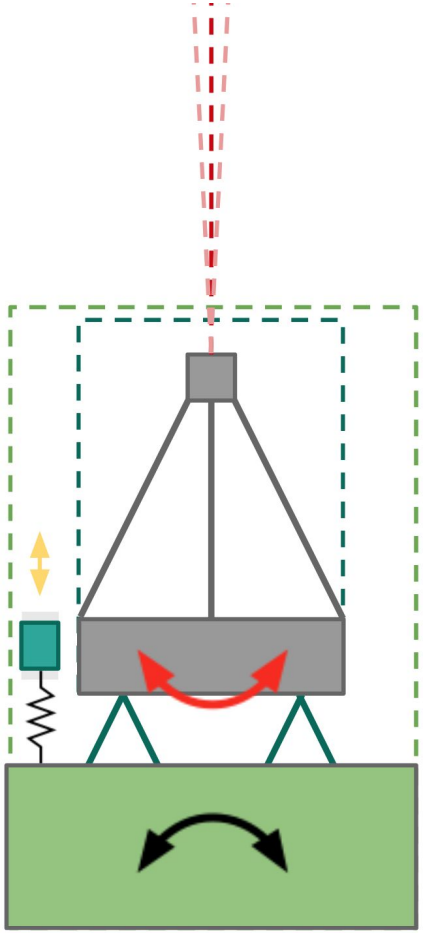




Optical Stabilization System (OIS)

Shake it up!

- Mass-spring-damper with feedback control algorithm
  - Voice coils induce vibration in orthogonal directions at approximate resonant frequency
  - Accelerometers on payload bus
- Requires in-space calibration, every satellite is different



OIS Calibration

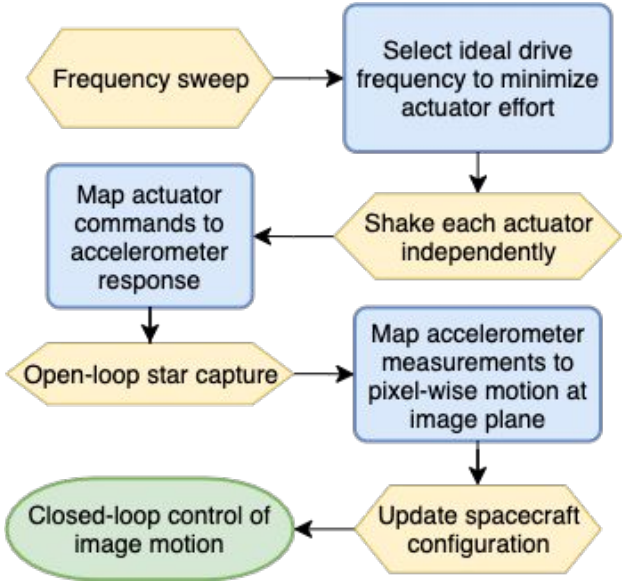
Calculating parameters automagically

1. SkySat executes calibration activity autonomously on orbit
2. SkySat downlinks high-fidelity telemetry
3. Analysis code imports telemetry and calculates calibration parameters
4. Repeat for next calibration step

OIS Calibration

Sequential workflow for a modern world

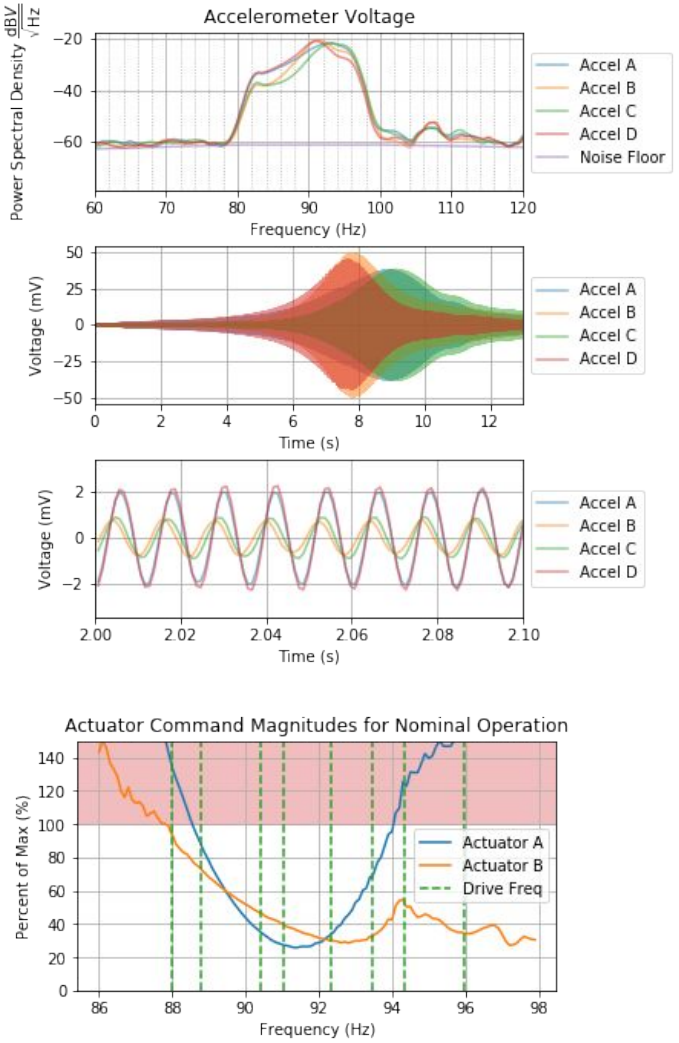
1. Select the optimum drive frequency
2. Map actuator commands to real vibration response
3. Map 3D payload bus vibration to 2D image motion at the focal plane
4. Close the loop: actuators use 3D accelerations as feedback to control 2D image motion



OIS Calibration

Choosing a drive frequency

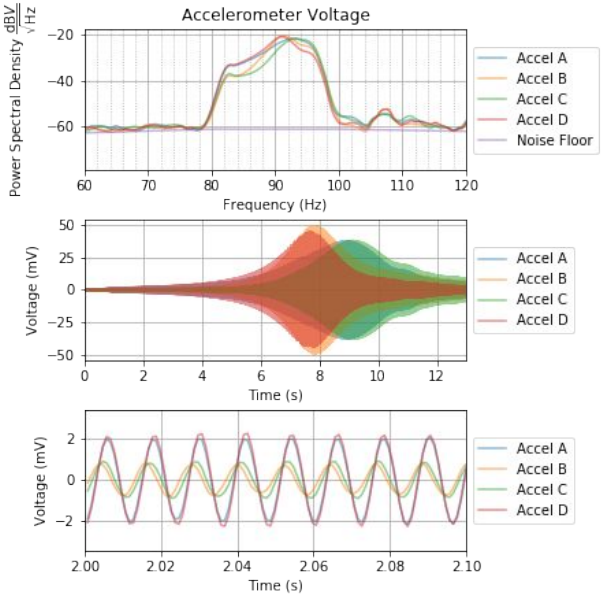
- Shake each actuator at 88-96Hz in 1Hz intervals, measure bus accelerations
- 8 available drive frequencies
- Choose frequency that produces the largest displacement for the least effort in both directions



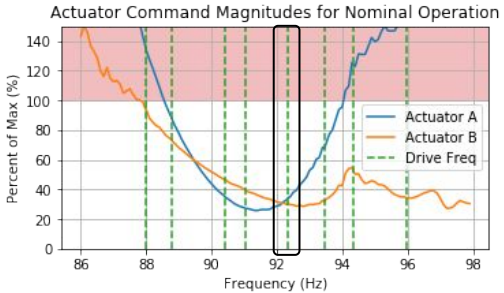
OIS Calibration

Plant characterization

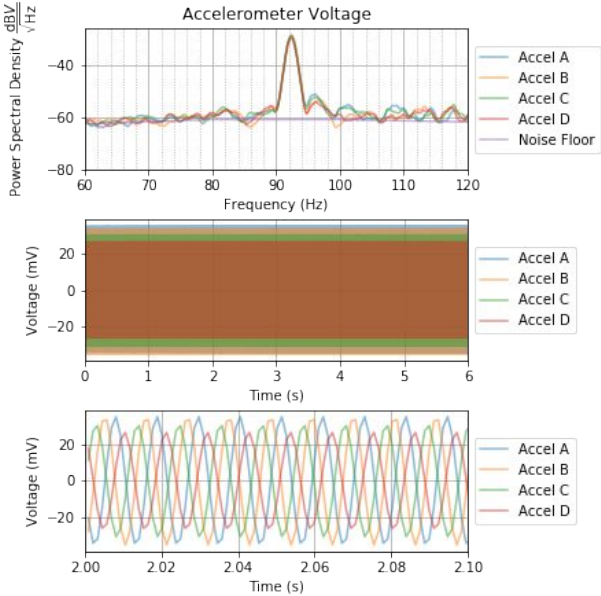
1. Sweep all frequencies



2. Select drive freq. to minimize actuator effort



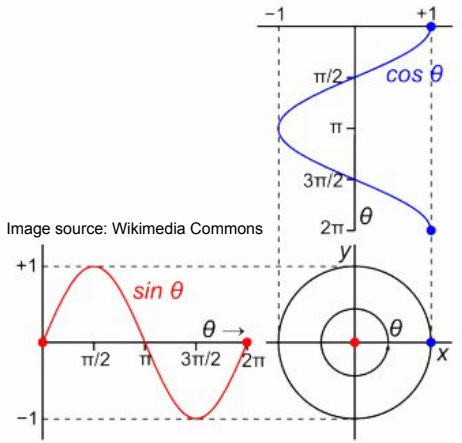
3. Map actuator input to accelerometer response

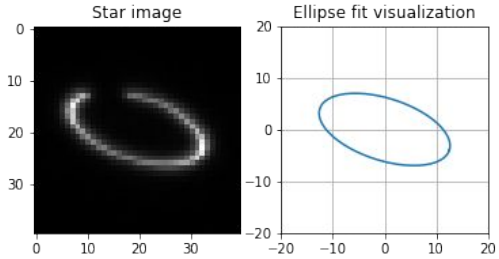


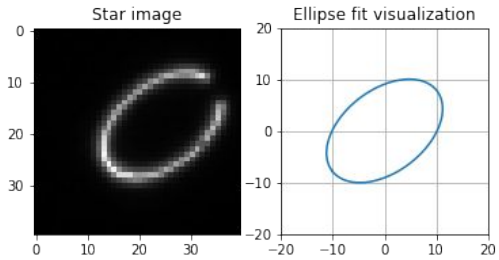
OIS Calibration

Mapping 3D vibration to 2D image motion

- Use stars as point sources, exposure leaves a trace as image plane moves to observe image motion for known actuator inputs
- Orthogonal sine waves over time look like ellipses when projected on the image plane
- Find oscillation parameters by fitting ellipses to the traces



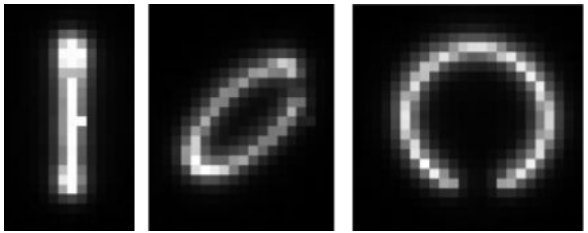




OIS Calibration

Fully defined 2-axis control

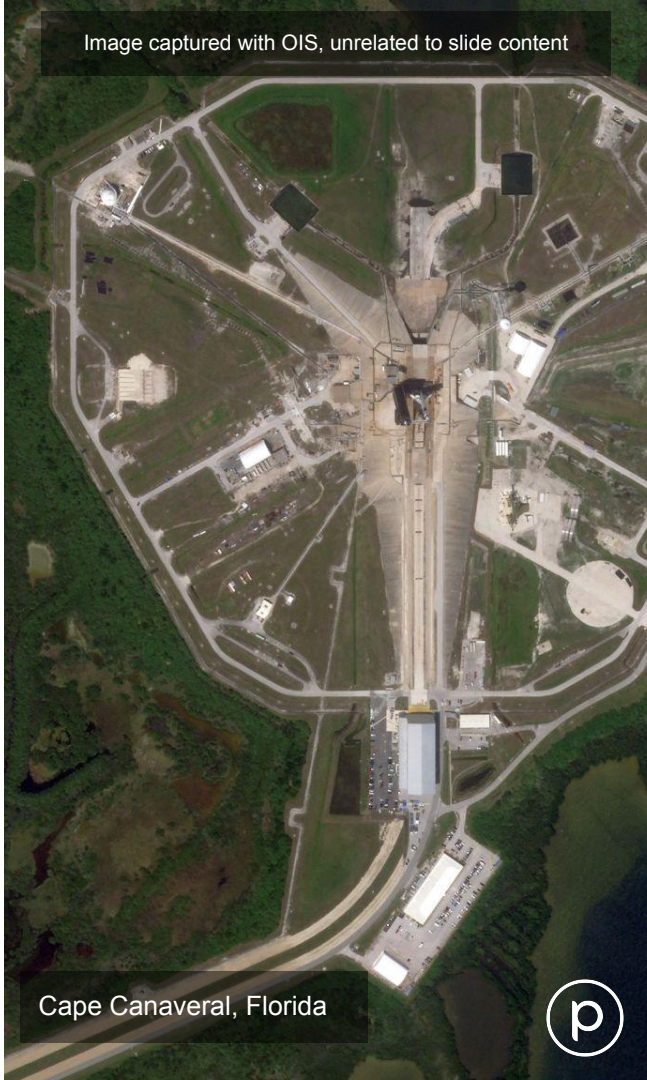
- Image motion is mathematically linked to observed bus accelerations
- Feedback control algorithm uses accelerometer measurements in closed-loop control of actuators
- Controlled in-track and cross-track sinusoidal motion mitigates motion blur while imaging



Scaling with Automation

A point-and-click adventure

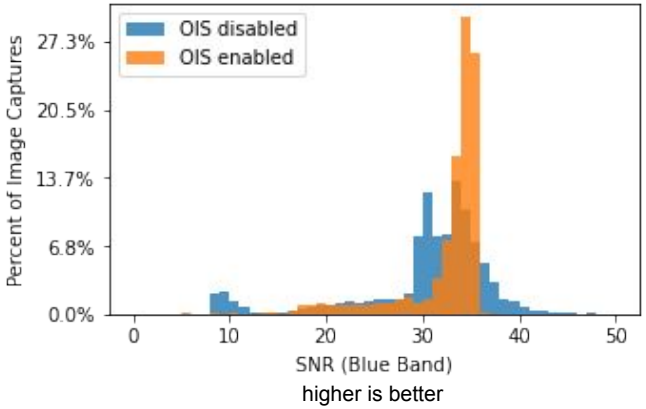
- Calibration activities are templates of commands
- Automated scheduling & execution
- One-click **automated analysis** and configuration updates
- Code integrated with written procedures
- **No subject matter expert required**

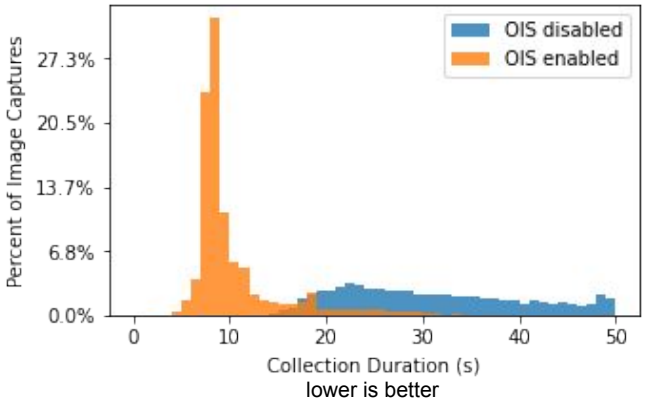


Impact of OIS

Better, faster, stronger

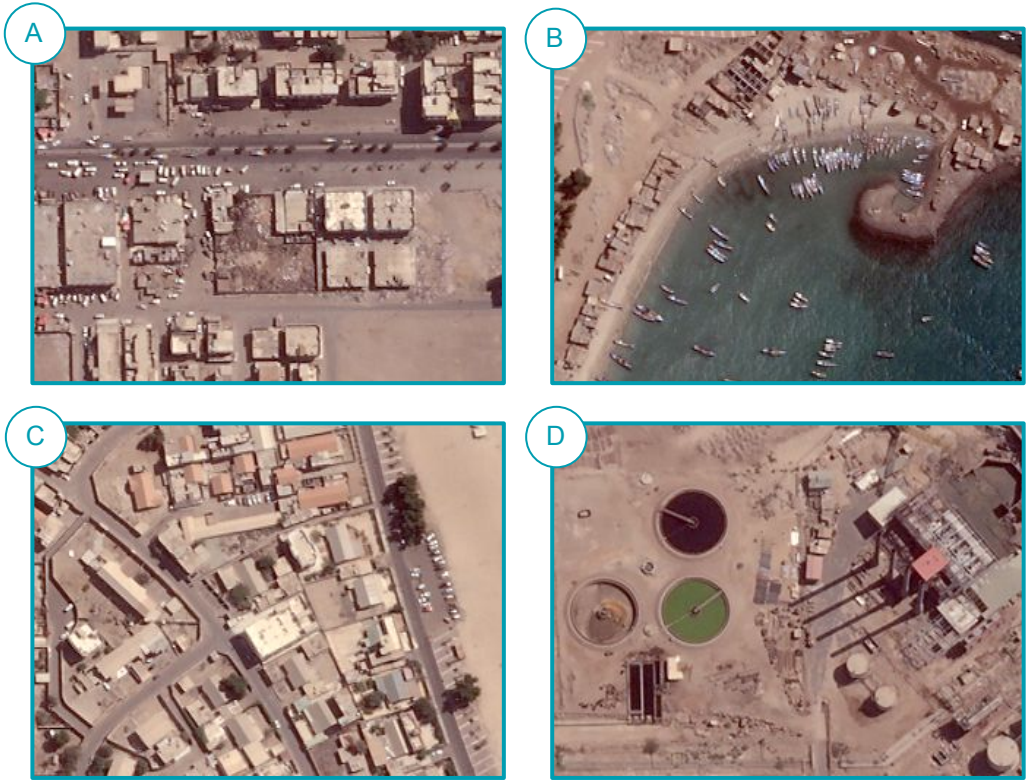
- Capturing images faster means more captures per orbit
- Signal-to-noise ratio is maintained
- Motion blur is constrained to less than 1 pixel





SkySat Optical Image Stabilization

Shaken, not blurred



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Monte Fitz Roy, Patagonia – March 19, 2018